DENSITY OF LIQUID ALKALI METALS

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With the aid of the thermodynamic similarity method generalized equations for the density of liquid alkali metals are obtained. Values of the density of liquid rubidium and cesium are calculated up to 600° C.

It is well known that the alkali metals (sodium, potassium, rubidium, and cesium) form a group of thermodynamically similar substances. X-ray studies have shown that the form of atomic packing in the metal (short-range order) is preserved in the liquid state at temperatures significantly exceeding the melting point. It is known that the density of liquids depends on the temperature and is practically independent of pressure. The melting point can be taken as the corresponding temperature with sufficient accuracy [1].

From the foregoing it follows that the density of the liquid metals forming the given group of thermodynamically similar substances must be a function of the atomic masses m of the elements concerned, the interatomic distance d (or atomic radius r = d/2) at the melting point, and the reduced temperature T/T_m:

$$\rho = \frac{m}{r^3} f\left(\frac{T}{T_m}\right), \tag{1}$$

where $f(T/T_m)$ is a universal function for the given group of thermodynamically similar liquid metals.

Values of the atomic masses and atomic radii are: for sodium, 22.99 amu and 1.883 Å; for potassium, 39.096 and 2.335; for rubidium, 85.48 and 2.502; for cesium, 132.91 and 2.690; and for lithium, 6.94 and 1.536. The atomic radii of the metals at the melting point were determined from the known relationship for a body-centered cubic lattice [2]. To determine the density of the liquid metals, we used experimental data for sodium and potassium from 100 up to 700° C [3], for rubidium from 39 up to 220.1° C, and for cesium from 28.5 up to 210.9° C [4].

Results of calculations of $f(T/T_m) = \rho r^3/m$ are presented in the figure, from which it is seen that the function $f(T/T_m)$ is expressed as a single straight line, which can be represented by the equation

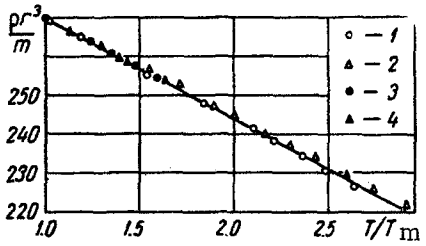
$$f(T/T_m) = 269.5\,[1 - 0.097\,(T/T_m - 1)]. \tag{2}$$

Thus, the generalized relationship for determining the density of liquid sodium, potassium, rubidium, and cesium has the form

$$\rho = \frac{269.5m}{r^3}\left[1 - 0.097\left(\frac{T}{T_m} - 1\right)\right]. \tag{3}$$

From equation (3) it is possible to determine values of the density of liquid alkali metals in the reduced temperature range $1 \leq T/T_m \leq 2.9$.

The available experimental data on the density of sodium, potassium, rubidium, and cesium agree well with values calculated from equation (3). In the high-temperature region the deviation of the calculated values from available experimental values does not exceed 0.5%, i.e., lies practically within the limits of experimental error.



The relation $\rho r^3/m = f(T/T_m)$ for liquid alkali metals: 1) sodium; 2) potassium; 3) rubidium; 4) cesium

The generalized relation (3) was used for calculating the density of liquid rubidium and cesium at temperatures up to 600° C (see table).

It is interesting to point out that the relation (3) also proved to be accurate for liquid lithium, which crystallizes like sodium, potassium, rubidium, and cesium in a body-centered cubic lattice, although with respect to a series of other features lithium can not be considered one of the above-mentioned thermodynamically similar group of substances. The deviations of values of the density of liquid lithium, obtained using equation (3), from the experimental data lie within limits of 1%.

Density of Liquid Rubidium and Cesium

Rubidium			Cesium		
t, °C	ρ_{calc}, kg/m^3	ρ_{exp}, kg/m^3	t, °C	ρ_{calc}, kg/m^3	ρ_{exp}, kg/m^3
39	1472	1472	28.5	1841	1841
99.7	1443	1442	99.6	1799	1797
140.5	1425	1423	140.5	1775	1773
179	1407	1405	210.9	1733	1732
220.1	1388	1387	250	1710	—
250	1374	—	300	1680	—
300	1352	—	350	1651	—
350	1329	—	400	1621	—
400	1306	—	450	1591	—
450	1283	—	500	1562	—
500	1260	—	550	1532	—
550	1237	—	600	1503	—
600	1214	—	—	—	—

REFERENCES

1. S. S. Kutateladze, V. M. Borishanskii, I. I. Novikov, and O. S. Fedynskii, Liquid Metal Coolants [in Russian], Atomizdat, 1958.

2. N. A. Shishakov, Basic Principles of Structural Analysis [in Russian], Izd. AN SSSR: 1961.

3. N. A. Nikol'skii, N. A. Kalakutskaya, et al., Collection: Problems of Heat Transfer [in Russian], Izd. AN SSSR, 1959.

4. N. B. Vargaftik, Handbook of the Thermophysical Properties of Liquids and Gases [in Russian], Fizmatgiz, 1963.

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